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Fiscal Sustainability of Eurozone Governments: An Empirical Review of the Past Decade

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Abstract

We provide an empirical review of fiscal sustainability of Eurozone governments by using quarterly data on debt to Gross Domestic Product (GDP) and primary deficit to GDP over the period 1999 to 2010. We verify the conditions of fiscal sustainability, defined by the government's present value borrowing constraint, by applying unit root tests that involve one, two, or multiple structural breaks. We select the best performing model of structural breaks and group Eurozone governments with respect to fiscal sustainability.

Keywords: European Monetary Union, public finances, structural breaks, global financial and economic crises

1. Introduction

In the 1990s, the European Union (EU) countries established the Economic and Monetary Union (EMU or Eurozone, henceforth) and adopted the Euro as a common currency. The EU member states have accepted various criteria, the so-called 'Maastricht convergence criteria', for the entrance to the Eurozone. The Maastricht public finance criteria have been included in the Stability and Growth Pact (SGP). In the SGP, the member states of the EMU committed themselves to strict public financial rules: a maximum government debt to Gross Domestic Product (GDP) of 60% and a maximum budget deficit to GDP of 3%. The European Commission (EC) has been responsible for enforcing the SGP and verifying the quality of statistical data reported by national governments. In 1998, 11 EU member states had met the Maastricht criteria, and the Eurozone initiated with the official launch of the Euro on 1 January 1999 with the following member states: Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. Since 1999 other EU-member states have joined the EMU: Greece in 2001; Slovenia in 2007; Cyprus, Malta and Slovakia in 2008; Estonia in 2011; Latvia in 2014.

The present article is motivated by the fact that several governments of the Eurozone have experienced high deficit and an increasing level of public debt as a consequence of the 2008 subprime mortgage crisis of the United States (US) and the subsequent global economic and financial meltdown. This has initiated debates about fiscal sustainability, crisis management and the prevention of future crises in the Eurozone. See Gros and Mayer (2010), and Marzinotto, Pisani-Ferry, and Sapir (2010). Due to the global development of financial markets experienced in the past decades, financial institutions and governments have become significantly interrelated. Consequently, an indebted national government may affect negatively the financial sector. On the other hand, a financial sector with large losses, for example due to an outsized real estate bubble, may generate default of public finances. See Dabrowski (2010), Gros (2010), and Lachman (2010). Several authors report that the sovereign debt crisis for some countries of the Eurozone has been related with the significant and unsustainable debt accumulation of the private sector (e.g., Ireland and Spain), while in other countries with the governments' mismanagement of public finances (e.g., Greece and Portugal). See De Grauwe (2010), Gros (2010), Arghyrou and Tsoukalas (2011), Featherstone (2011), and Mamadouh and van der Wusten (2011).

We provide an empirical analysis of Eurozone government debt sustainability based on historical data. We use different unit root tests for the debt to GDP and primary deficit to GDP to evaluate the fiscal sustainability of Eurozone governments over the past decade. These unit root tests may involve one, two, or multiple structural breaks. Our framework extends the classical test of fiscal sustainability of Hamilton and Flavin (1986), where the Augmented Dickey-Fuller (ADF, 1979) unit root test is applied. The tests proposed in this article may have more statistical power in periods of economic crisis than the ADF test. Furthermore, they estimate breakpoint dates endogenously, providing additional information about the evolution of fiscal ratios and fiscal sustainability.

The statistical findings presented in this article provide an empirical review of government finances from 1999 to 2010. The results reported show how the evolution of fiscal ratios may have affected sovereign debt investors' beliefs about government debt sustainability and sovereign credit risk in the Eurozone over the past decade.

The remaining part of this article is organized as follows. Section 2 describes the economic foundation of fiscal sustainability tests: the government's present value borrowing constraint. Section 3 reviews the fiscal data applied. Section 4 summarizes the classical ADF test results on fiscal sustainability. Section 5 reports the extended unit root test results on fiscal sustainability. Robustness analysis results are reported in Section 6. Finally, we summarize and conclude in Section 7.

2. Fiscal Sustainability

In the existing literature, several papers argue that the government is subject to a present value borrowing constraint (e.g., Hamilton & Flavin,1986; Trehan & Walsh, 1991; Alfonso & Rault, 2007; Hallett & Lewis, 2007), which establishes that the present value of the current stock of sovereign debt is identical to the present value of future fiscal balances. The government's borrowing constraint can be derived as follows. The current sovereign debt level, B_t can be expressed as the sum of the debt in the previous period, the corresponding interest payments, $r_t B_{t-1}$ and the current primary deficit, PD_t:

$$B_t = (1 + r_t)B_{t-1} + PD_t \tag{1}$$

Dividing this equation by the GDP denoted by G_t, we get

$$\frac{B_t}{G_t} = \frac{B_{t-1}(1+r_t)}{G_{t-1}(1+g_t)} + \frac{PD_t}{G_t} \tag{2}$$

where g_t denotes the GDP growth rate. It can be derived from these equations that the government's present value borrowing constraint at $t = 0$ for an infinite time horizon is given by

$$b_0 = \lim_{t\to\infty} b_t \left(\frac{1+r_t}{1+g_t}\right)^{-t} - \sum_{t=1}^{\infty} pd_t \left(\frac{1+r_t}{1+g_t}\right)^{-t} \tag{3}$$

where $b_t = B_t/G_t$ and $pd_t = PD_t/G_t$. The present value borrowing constraint has been used to define the concept of fiscal sustainability in the literature. Moreover, it has also motivated statistical tests of fiscal sustainability, since fiscal sustainability requires both b_t and pd_t to be non-explosive according to Equation (3).

Several authors have proposed the application of unit root tests for fiscal variables to verify fiscal sustainability (e.g., Hamilton & Flavin 1986; Trehan & Walsh 1991; Alfonso & Rault, 2007). Hamilton and Flavin (1986) use ADF unit root tests to verify the sustainability of US government debt. Trehan and Walsh (1991), in a unit root test framework, state: 'We call a budget process sustainable if the expected present discounted value of the implied future stock of debt converges to zero.' Furthermore, Alfonso and Rault (2007) state that the stationarity of government debt is a required for the fiscal sustainability of EU governments. Using different unit root tests, these authors conclude that: 'Sustainability of a given fiscal position requires that all national debt be eventually repaid. The debt ratio must be non-explosive and must ultimately converge on some finite limit.'

3. Sovereign Debt and Deficit Data

We use data on quarterly public debt to GDP and primary deficit to GDP ratios for the period 1990 to 2010 obtained from the Eurostat Statistics Database of the EC. Since the quarterly deficit to GDP ratios exhibit significant seasonality effects, we use the Holt-Winters exponential smoothing method to remove the seasonality component from these data (see Holt, 1959; Winters, 1960). The list of countries analyzed, the corresponding period observed for each state and some descriptive statistics for debt to GDP and smoothed primary deficit to GDP data are presented in Tables 1 and 2, respectively. In this article, we focus on the 17 member states which joined the Eurozone before 2014.

Table 1 shows that the debt to GDP ratio is heterogeneous within the Eurozone. Greece has the maximum value of debt to GDP (142.80%), while Estonia presents the lowest debt to GDP ratio (3.40%) over the sample period. Table 1 also shows that the countries with the highest mean debt to GDP ratio are Italy (110.34%), Greece (108.60%) and Belgium (100.78%). Moreover, the highest standard deviations (SDs) of debt to GDP over the period analyzed are exhibited by: Ireland (17.91%), Portugal (12.29%) and Greece (11.67%), reflecting substantial changes in the public debt levels over the period 2000 to 2010.

Table 2 exhibits that the statistics of the smoothed primary deficit to GDP ratio are very different in each country of the Eurozone. Ireland has the maximum value of primary deficit to GDP (29.53%), while Finland presents the lowest deficit to GDP ratio (-9.24%) over the sample period. Table 2 also shows that the countries with the highest mean deficit to GDP ratio are Slovakia (2.39%), Portugal (2.14%) and Greece (2.01%). Moreover, the highest SDs of deficit to GDP over the period analyzed are exhibited by: Ireland (9.02%), Spain (6.09%) and Greece (4.20%), evidencing high volatility in the government deficit to GDP levels during the last decade.

Table 1. Descriptive statistics of the government debt to GDP ratio

Country	Start	End	T	Mean	Med	Max	Min	SD	Skew	Kurt
Austria	2000 Q1	2010 Q4	44	68.582	69.700	72.700	60.700	3.298	-0.930	-0.122
Belgium	1999 Q1	2010 Q4	48	100.783	99.650	120.100	84.200	9.500	0.273	-0.786
Cyprus	2000 Q1	2010 Q4	44	63.068	64.000	73.000	48.300	6.450	-0.615	-0.355
Estonia	2000 Q1	2010 Q4	44	5.100	5.000	7.200	3.400	0.941	0.373	-0.168
Finland	2000 Q1	2010 Q4	44	40.975	41.450	48.400	30.000	4.285	-0.502	-0.186
France	1999 Q1	2010 Q4	48	64.821	64.800	82.900	56.400	7.128	1.153	0.763
Germany	2000 Q1	2010 Q4	44	65.764	65.700	83.200	58.300	5.299	0.898	1.370
Greece	2000 Q4	2010 Q4	41	108.602	104.700	142.800	97.300	11.669	1.636	1.756
Ireland	2000 Q1	2010 Q4	44	39.741	32.600	96.200	24.700	17.906	1.894	2.873
Italy	1999 Q1	2010 Q4	48	110.335	109.050	119.600	103.600	4.381	0.629	-0.568
Luxembourg	2000 Q1	2010 Q4	44	8.241	6.300	19.600	5.500	4.121	1.731	1.564
Malta	2000 Q4	2010 Q4	41	65.361	65.300	73.300	55.900	4.479	-0.020	-0.854
Netherlands	2000 Q1	2010 Q4	44	53.520	52.400	63.100	45.300	5.140	0.494	-0.736
Portugal	2000 Q1	2010 Q4	44	63.095	60.550	93.000	48.200	12.285	0.841	-0.091
Slovakia	2000 Q1	2010 Q4	44	38.816	38.550	51.700	25.800	7.897	0.055	-1.193
Slovenia	2000 Q1	2010 Q4	44	27.870	27.200	38.000	21.900	4.081	1.357	1.554
Spain	2000 Q1	2010 Q4	44	48.539	48.700	61.000	35.300	7.854	-0.081	-1.238

Description: The scale of the data series is in percentage points. The columns Start and End show the first and last quarter observed for each country, respectively. T, Med, Max, Min, SD, Skew and Kurt denote sample size, median, maximum, minimum, standard deviation, skewness, and kurtosis, respectively.

Table 2. Descriptive statistics of the smoothed primary deficit to GDP ratio

Country	Start	End	T	Mean	Med	Max	Min	SD	Skew	Kurt
Austria	1999 Q1	2010 Q4	48	-0.758	-0.735	0.762	-1.874	0.612	0.264	2.806
Belgium	1999 Q1	2010 Q4	48	-3.009	-3.021	1.710	-6.488	2.316	0.393	2.242
Cyprus	1999 Q1	2010 Q4	48	-1.249	-1.107	2.471	-7.405	2.293	-0.610	3.117
Estonia	1999 Q1	2010 Q4	48	-0.635	-1.093	4.270	-3.892	2.223	0.632	2.370
Finland	1999 Q1	2010 Q4	48	-5.024	-5.091	1.355	-9.240	2.452	0.781	3.637
France	1999 Q1	2010 Q4	48	0.859	0.502	4.409	-1.530	1.537	0.994	3.138
Germany	1999 Q1	2010 Q4	48	-0.554	-0.272	1.826	-5.222	1.647	-0.660	2.736
Greece	2000 Q1	2010 Q4	44	2.013	2.208	11.251	-6.840	4.201	0.202	3.142
Ireland	1999 Q1	2010 Q4	48	0.962	-2.452	29.529	-7.849	9.022	1.644	4.973
Italy	1999 Q1	2010 Q4	48	-1.575	-1.462	0.288	-3.691	1.013	-0.211	2.094
Luxembourg	1999 Q1	2010 Q4	48	-1.957	-1.730	1.608	-6.546	2.202	-0.338	2.133
Malta	2000 Q1	2010 Q4	44	0.892	0.260	10.820	-3.169	2.907	1.563	6.379
Netherlands	1999 Q1	2010 Q4	48	-1.602	-1.841	5.029	-6.167	2.470	0.677	3.282
Portugal	1999 Q1	2010 Q4	48	2.142	2.185	7.126	-2.780	2.139	-0.003	3.774
Slovakia	1999 Q1	2010 Q4	48	2.378	1.665	7.664	-0.397	2.104	0.670	2.356
Slovenia	1999 Q1	2010 Q4	48	1.162	0.787	5.999	-1.637	1.703	1.293	4.212
Spain	2000 Q1	2010 Q4	44	-0.626	-2.398	15.388	-8.900	6.089	1.326	4.161

Description: The scale of the data series is in percentage points. Deficit to GDP data have been smoothed by using the Holt-Winters exponential smoothing technique (Holt, 1959; Winters, 1960). The columns Start and End show the first and last quarter observed for each country, respectively. T, Med, Max, Min, SD, Skew and Kurt denote sample size, median, maximum, minimum, standard deviation, skewness, and kurtosis, respectively.

4. Classical Test of Fiscal Sustainability

We study the fiscal sustainability of Eurozone governments by testing if government debt to GDP and primary deficit to GDP ratios are stationarity or explosive over the period 1990 to 2010. We perform different unit root tests for these fiscal ratios. The null hypothesis, H_0 of these tests is that fiscal data form an unstable unit root process, while according to the alternative hypothesis, H_1 fiscal ratios are covariance stationary. See the definitions of covariance stationary and unit root processes in Hamilton (1994).

In the remaining part of this article, y_t is used to denote both debt to GDP and primary deficit to GDP ratios. The initial unit root test employed is the ADF test with a constant term. The ADF test is performed by estimating the following regression model:

$$\Delta y_t = \delta' Z_t + \varphi y_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + e_t \quad (4)$$

where $\Delta y_t = y_t - y_{t-1}$ denotes the first difference of y_t, the deterministic terms are given by $Z_t = 1$, k augmentation terms, Δy_{t-j} with $j = 1, \dots, k$, are added to eliminate possible serial correlation and e_t is an i.i.d. error term with zero mean and finite variance.

The first column of Tables 3 and 4 presents the ADF test statistics for debt to GDP and primary deficit to GDP, respectively. These tables show that the unit root null hypothesis can be rejected only for Austria for both fiscal ratios. Therefore, according to the approach of Hamilton and Flavin (1986), the evolution of the debt to GDP ratio is not compatible with fiscal sustainability for the other 16 member states of the Eurozone. We conclude that 16 countries from the 17 EMU states have unsustainable public finances according to the ADF test.

Table 3. Unit root tests with constant term for the government debt to GDP ratio

Country	ADF	R_a^2	LS (2004)	T_B	R_a^2	LS (2003)	T_{1B}	T_{2B}	R_a^2
Austria	-3.431**	43.08%	-3.689**	2005 Q3	54.22%	**-4.375*** **	**2005 Q3**	**2007 Q2**	**59.51%**
Belgium	-2.197(UR)	57.91%	-2.856(UR)	2009 Q3	60.15%	**-3.299*** **	**2003 Q3**	**2007 Q4**	**60.87%**
Cyprus	-2.216(UR)	6.33%	**-2.457(UR)**	**2008 Q2**	**20.70%**	-2.672(UR)	2007 Q1	2009 Q4	15.64%
Estonia	-1.418(UR)	16.37%	-2.762(UR)	2007 Q3	14.39%	**-2.950***	**2005 Q3**	**2007 Q3**	**16.41%**
Finland	-1.089(UR)	4.41%	-2.781(UR)	2008 Q3	29.85%	**-3.532** **	**2004 Q4**	**2008 Q3**	**42.59%**
France	0.629(UR)	12.78%	-4.026**	2007 Q1	37.60%	**-4.376*** **	**2003 Q3**	**2007 Q1**	**40.85%**
Germany	1.680(UR)	8.25%	-2.484(UR)	2008 Q4	28.99%	**-3.234** **	**2009 Q1**	**2009 Q4**	**31.10%**
Greece	2.148(UR)	19.65%	-1.953(UR)	2004 Q3	23.39%	**-2.063(UR)**	**2004 Q3**	**2005 Q4**	**27.37%**
Ireland	2.202(UR)	24.94%	-2.344(UR)	2009 Q2	42.08%	**-2.758(UR)**	**2002 Q3**	**2009 Q2**	**56.12%**
Italy	-1.546(UR)	49.89%	-3.026(UR)	2007 Q4	46.46%	**-3.842*** **	**2002 Q3**	**2008 Q4**	**67.02%**
Luxembourg	0.658(UR)	-1.72%	**-2.109(UR)**	**2008 Q3**	**77.99%**	-2.656(UR)	2003 Q4	2008 Q3	73.88%
Malta	-1.980(UR)	11.17%	**-2.124(UR)**	**2006 Q1**	**17.02%**	-2.267(UR)	2004 Q3	2006 Q1	15.12%
Netherlands	-1.445(UR)	2.02%	-1.787(UR)	2008 Q3	77.44%	**-3.037**	**2003 Q1**	**2008 Q3**	**81.25%**
Portugal	3.296(UR)	17.95%	-2.673(UR)	2009 Q1	21.26%	**-2.967***	**2009 Q1**	**2009 Q3**	**25.43%**
Slovakia	-1.790(UR)	1.17%	-2.075(UR)	2007 Q2	18.51%	**-2.613(UR)**	**2005 Q1**	**2007 Q4**	**34.39%**
Slovenia	-0.917(UR)	5.12%	**-2.026(UR)**	**2009 Q1**	**27.83%**	-2.479(UR)	2005 Q1	2009 Q3	18.26%
Spain	-1.383(UR)	63.17%	**-2.722(UR)**	**2008 Q4**	**78.18%**	-2.909*	2003 Q2	2008 Q4	70.05%

Description: Augmented Dickey-Fuller (ADF). Lee and Strazicich (LS). Unit Root (UR). T_B and T_{iB} denote the quarter of the structural change. Bold numbers indicate the model with the highest adjusted R-squared, R_a^2, value for each country. The adjusted R-squared is computed by $R_a^2 = 1 - (1 - R^2)(1 - T)/(1 - k - T)$, where R^2 corresponds to the R-squared of the regressions of Equations (4) and (5). Moreover, T is the sample size and k denotes the number of parameters in each equation. Bold numbers indicate the model with the highest R_a^2 value. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 4. Unit root tests with constant term for the smoothed primary deficit to GDP ratio

Country	ADF	${R_a}^2$	LS (2004)	T_B	${R_a}^2$	LS (2003)	T_{1B}	T_{2B}	${R_a}^2$
Austria	-3.219**	24.86%	-3.865**	2004 Q1	30.60%	**-4.730*** **	**2004 Q1**	**2009 Q1**	**43.47%**
Belgium	-0.771(UR)	72.33%	-1.853(UR)	2003 Q1	73.57%	**-2.571(UR)**	**2005 Q1**	**2009 Q1**	**78.21%**
Cyprus	-1.998(UR)	60.17%	-5.193***	2005 Q1	68.97%	**-5.890*** **	**2003 Q4**	**2008 Q4**	**72.24%**
Estonia	-2.259(UR)	35.94%	-3.515*	2006 Q4	39.55%	**-3.811*** **	**2007 Q4**	**2009 Q3**	**44.47%**
Finland	-2.143(UR)	80.77%	-5.634***	2008 Q4	86.43%	**-6.892*** **	**2001 Q4**	**2009 Q1**	**89.42%**
France	-1.599(UR)	83.57%	-3.267*	2007 Q1	85.94%	**-3.862*** **	**2001 Q2**	**2009 Q2**	**86.73%**
Germany	-2.109(UR)	41.17%	-3.937**	2009 Q3	58.67%	**-4.723*** **	**2000 Q4**	**2008 Q3**	**67.58%**
Greece	-1.971(UR)	25.71%	**-3.014(UR)**	**2009 Q2**	**31.30%**	-3.465**	2004 Q3	2009 Q2	21.26%
Ireland	2.706(UR)	52.62%	-1.737(UR)	2008 Q3	62.32%	**-2.415(UR)**	**2003 Q4**	**2006 Q3**	**63.18%**
Italy	-1.354(UR)	59.74%	-3.356*	2002 Q4	64.86%	**-3.924*** **	**2001 Q1**	**2009 Q1**	**69.96%**
Luxembourg	-2.385(UR)	62.76%	-4.292***	2001 Q3	66.55%	**-4.824*** **	**2003 Q1**	**2009 Q2**	**66.91%**
Malta	-2.544(UR)	19.90%	-2.554(UR)	2002 Q3	17.76%	**-3.197** **	**2003 Q2**	**2008 Q1**	**33.83%**
Netherlands	-2.144(UR)	51.49%	-3.747**	2008 Q2	52.04%	**-4.218*** **	**2001 Q2**	**2009 Q2**	**58.45%**
Portugal	-2.417(UR)	38.13%	**-2.277(UR)**	**2008 Q3**	**41.17%**	-2.868*	2003 Q4	2008 Q3	39.26%
Slovakia	-2.161(UR)	60.65%	-3.081(UR)	2002 Q4	61.04%	**-3.879*** **	**2002 Q1**	**2009 Q1**	**64.24%**
Slovenia	-2.600(UR)	30.71%	-2.627(UR)	2008 Q1	28.63%	**-2.803* **	**2001 Q2**	**2009 Q1**	**31.53%**
Spain	-0.836(UR)	66.91%	-4.140**	2008 Q4	76.86%	**-5.228*** **	**2002 Q3**	**2009 Q1**	**91.72%**

Description: Augmented Dickey-Fuller (ADF). Lee and Strazicich (LS). Unit Root (UR). T_B and T_{iB} denote the quarter of the structural change. Bold numbers indicate the model with the highest adjusted R-squared, R_a^2, value for each country. The adjusted R-squared is computed by $R_a^2 = 1-(1-R^2)(1-T)/(1-k-T)$, where R^2 corresponds to the R-squared of the regressions of Equations (4) and (5). Moreover, T is the sample size and k denotes the number of parameters in each equation. Bold numbers indicate the model with the highest R_a^2 value. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

5. Extended Tests of Fiscal Sustainability

The financial, economic and public debt crises in the Eurozone of the last years implied structural breaks in public finance ratios in several countries. These motivate the application of more general unit root tests that account for structural changes in the public finances of Eurozone member states. The unit root tests with structural breaks considered in this article verify a weaker form of fiscal sustainability since they imply non-stationary time series under both H_0 and H_1 hypotheses. However, they may evidence stationary behavior around the estimated structural change dates when the H_0 unit root hypothesis is rejected, which would imply predictable fiscal time series. Moreover, the extended unit root tests proposed in this article identify the dates of structural changes over the period 1990 to 2010 in an endogenous manner.

In the following, we briefly review existing unit root tests that incorporate structural changes. There are several unit root tests in the econometric literature which consider the possibility of one structural break in the data series. Perron (1989) considers a unit root test with one structural break with known (exogenous) breakpoint date. This paper has been extended by Zivot and Andrews (1992) who determine the structural breakpoint date endogenously. Additional works that estimate the time of the break endogenously in unit root tests are Perron (1997) and Vogelsang and Perron (1998).

Lee and Strazicich (LS, henceforth, 2004) argue that one important issue regarding these endogenous break point unit root tests is that they omit the possibility of a unit root with break under the null hypothesis. Therefore, spurious rejections of H_0 may occur, questioning the statistical validity of these tests. Furthermore, unit root tests with a single structural break do not take into account that several changes may occur in the level of the variable of interest. This fact has motivated Lumsdaine and Papell (1997) to extend the analysis of Zivot and Andrews (1992) to include two structural breaks. However, Lumsdaine and Pappel (1997) have not considered structural breaks under the null hypothesis in their model. Therefore, spurious rejections may occur as it was noted previously.

LS (2004) and LS (2003) have addressed the problem of spurious rejection of H_0 by introducing unit root tests with one and two breaks, respectively, considering structural break(s) under the null hypothesis. The LS tests applied in this article allow for structural change(s) in the model's constant term. Moreover, these structural breakpoint dates are identified endogenously in these tests. In the LS (2003, 2004) tests, the following equation is estimated:

$$\Delta y_t = \delta' \Delta Z_t + \varphi \tilde{S}_{t-1} + \sum_{j=1}^{k} c_j \Delta \tilde{S}_{t-j} + e_t \quad (5)$$

where $\tilde{S}_t = y_t - \widetilde{\Psi}_1 - Z_t \tilde{\delta}$ and $\widetilde{\Psi}_1 = y_1 = Z_1 \tilde{\delta}$. The $\tilde{\delta}$ parameters denote coefficients estimated by a regression of Δy_t on ΔZ_t. Moreover, k augmentation terms, $\Delta \tilde{S}_{t-j}$ with $j = 1, \dots, k$, are included to correct for serial correlation of the error terms e_t. See LS (2004) for the selection of the number of augmentation terms, k in Equation (5). In LS (2004), $Z_t = (1, t, D_t)'$ and $\Delta Z_t = (1, \Delta D_t)'$. Therefore, this model includes one date of structural change in the constant parameter. In LS (2003), $Z_t = (1, t, D_{1t}, D_{2t})'$ and $\Delta Z_t = (1, \Delta D_{1t}, \Delta D_{2t})'$. Thus, this specification considers two different dates of structural changes in the constant parameter.

The unit root test results and the quarters of structural changes estimated by these models are shown in Tables 3 and 4 for the debt to GDP and deficit to GDP ratios, respectively. In order to choose the most appropriate model for the EMU fiscal data, we have computed the adjusted R-squared, R_a^2, for the test equation of the ADF and LS (2003, 2004) unit root tests. Table 3 and 4 report these metrics, indicating the best model by bold numbers. We can see in Tables 3 and 4 that the R_a^2 of the ADF test is lower than the model performance metric of LS (2003, 2004) in all cases. This confirms the application of structural changes when public finances of the Eurozone are analyzed over the period 1999 to 2010. In the following, we focus on the implications of the best econometric model identified by the highest R_a^2 estimates for each country.

Tables 3 and 4 for debt to GDP and deficit to GDP, respectively, report the number of structural changes and the corresponding breakpoint dates. For the debt to GDP variable, one structural break is found for Cyprus (2008 Q2), Luxembourg (2008 Q3), Malta (2006 Q1), Slovenia (2009 Q1) and Spain (2008 Q4). Moreover, two dates of structural changes in debt to GDP are evidenced for the rest of the Eurozone states. For the deficit to GDP variable, one structural break is estimated for Greece (2009 Q2) and Portugal (2008 Q3). For the rest of the EMU countries, two breaks are found in the deficit to GDP time series.

We find breaking level stationary debt to GDP for the following governments: Austria, Belgium, Estonia, Finland, France, Germany, Italy, and the Netherlands. These countries represent a suddenly increased and then stabilized level of debt to GDP. On the other hand, breaking level unit root process is found for government debt to GDP for Cyprus, Greece, Ireland, Luxembourg, Malta, Portugal, Slovakia, Slovenia, and Spain. In these countries, the debt to GDP time series is explosive according to the breaking level unit root tests. Furthermore, the best performing unit root test evidences breaking level unit root deficit to GDP for Greece, Ireland, and Portugal. For other EMU states, we find breaking level stationary deficit to GDP process.

6. Robustness Analysis

The unit root test results reported in Tables 3 and 4 show that, in several cases, the model with two structural breaks has the highest R_a^2 value. However, unit root tests with more than two structural breaks may explain better the evolution of the fiscal variables. To verify the robustness of the results for the unit root test with two structural breaks, we employed a unit root test with three structural breaks, extending the framework of LS (2003). We estimated Equation (5) with $Z_t = (1, t, D_{1t}, D_{2t}, D_{3t})'$ and $\Delta Z_t = (1, \Delta D_{1t}, \Delta D_{2t}, \Delta D_{3t})'$. The critical values of this test are obtained by 5000 replications of the model in a way similar to LS (2003). We perform the test with three structural breaks for the countries where the LS (2003) model has the highest R_a^2 value. In the testing procedure, we use the T_{1B} and T_{2B} dates estimated by the LS (2003) model (see Tables 3 and 4), while T_{3B} is determined endogenously. This approach is similar to the idea of Bai and Perron (1998), who test for l versus $l+1$ breaks conditioning on the locations of l breaks. See also Bai and Perron (2003) and Wang and Zivot (2000). Furthermore, conditioning on two previously estimated breaks, reduces the computation time substantially. We find that the R_a^2 of the three-break unit root test is lower than the R_a^2 of the two-break test for all governments. Therefore, two breakpoints are preferred to three breakpoints according to the R_a^2 metric.

7. Summary and Conclusions

We use different unit root tests to assess fiscal sustainability of all member states of the Eurozone over the period 1999 to 2010. We apply different unit root tests for sovereign debt to GDP and primary deficit to GDP ratios to verify the conditions of fiscal sustainability derived from the government's present value borrowing constraint. The classical ADF test has not evidenced fiscal sustainability for 16 of the 17 EMU member states. However, this test does not consider the possibility of structural breaks. Therefore, we have considered the unit root tests involving structural breaks, as suggested by LS (2003, 2004). These tests include one or two structural changes in the fiscal variables to capture shifts in public finances over the crisis period. The specifications proposed by LS (2003, 2004) have shown better performance than the ADF test when comparing the R_a^2 model selection metric of the different formulations. The LS (2003, 2004) tests identify endogenously the dates of structural changes for both the debt to GDP and primary deficit to GDP variables. We have tested for multiple structural breaks and have found that models with one or two structural breaks are superior according to the R_a^2 measure. Based on the unit root test results, we classify the EMU governments into three groups:

a) Explosive debt to GDP and deficit to GDP governments: Greece, Ireland, and Portugal.

b) Explosive debt to GDP and breaking level stationary deficit to GDP governments: Cyprus, Luxembourg, Malta, Slovakia, Slovenia, and Spain.

c) Breaking level stationary debt to GDP and deficit to GDP governments: Austria, Belgium, Estonia, Finland, France, Germany, Italy, and the Netherlands.

These results provide an empirical review of sovereign debt sustainability from 1999 to 2010 for the Eurozone. The statistical tests involving structural changes identify the breakpoint dates and they can be used to forecast the evolution of future government debt to GDP and primary deficit to GDP in the Eurozone states. The results reported show how the evolution of fiscal ratios may have affected sovereign debt investors' beliefs about government debt sustainability and sovereign credit risk in the Eurozone over the past decade. Furthermore, these results provide a clear insight on the correlation between fiscal sustainability of Eurozone countries and the EMU sovereign debt crisis.

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